



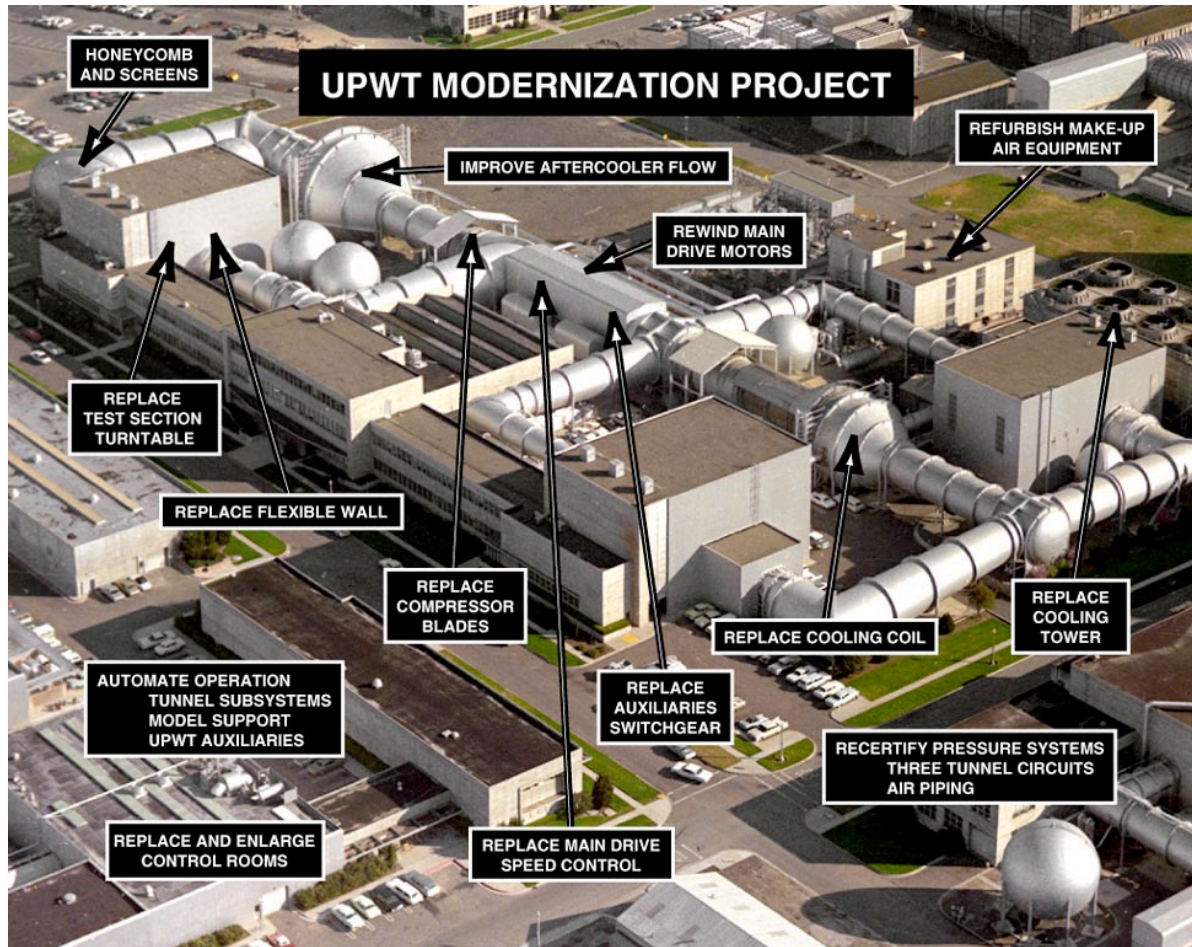
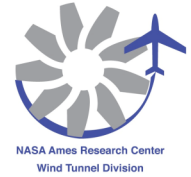
Flow Quality Survey of the NASA Ames 11-by 11-Ft Transonic Wind Tunnel

114th Meeting of the
Supersonic Tunnel Association International
Oct 3-7 2010
Japan



Introduction

Facility Description



Ames UPWT became operational in 1955 and consists of three test section legs

- 11-By 11-Foot Transonic Leg ($0.2 \leq \text{Mach} \leq 1.5$)

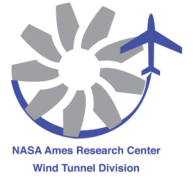
- 9-By 7-Foot Supersonic Leg ($1.5 \leq \text{Mach} \leq 2.54$)

- 8-By 7-Foot Supersonic Leg ($2.5 \leq \text{Mach} \leq 3.5$).....inactive

Variable pressure (0.2 to 2.2 Atm for the 11-by 11-Ft TWT)



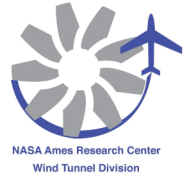
Background Post Modernization Survey



- A detailed turbulence and acoustics survey was in the late 1990's following the modernization of the 11-ft TWT. This survey was limited to Mach < 1.0.
- Results showed a significant improvement in the turbulence levels and flow uniformity both attributed to the addition of the turbulence reductions system.
- Tunnel background noise levels also showed significant improvements although no specific upgrades were made to address tunnel noise.
- Shortly after the survey, the composite compressor blades were removed and replaced due to structural failure. They were replaced with the original aluminum blades.
- A limited amount of data was published immediately following the survey. Plans were in place to fully document the remaining data but several factors prevented the plans from being executed.



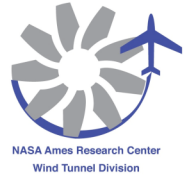
Why conduct another Flow Quality Survey?



- Recent trends in wind tunnel tested have indicated an interest in laminar flow wing development and design of next generation spacecraft.
- These types of test place a significant importance on knowing the turbulence and background noise levels of the 11-Ft TWT.
- Customers have expressed an interest in knowing the
 - flow quality at supersonic Mach numbers; an area not documented, and
 - detailed spectral content (PSD's) at all Mach numbers; important for separating model generated noise from tunnel background noise.
- Questions have arisen regarding the acoustics levels reported by the facility based on P' measurements made on customer models.
- Data from the post-modernization survey are no longer available.
- More recently, the turning vane set downstream of the test section (TV1) was replaced due to stress cracks in the structure.



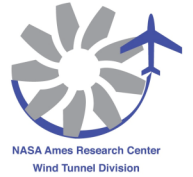
New Flow Quality Survey



In 2008, funding became available to conduct a new turbulence and acoustics survey.

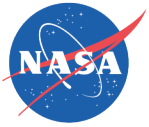
Objectives

- Measure free-stream turbulence and acoustics levels in the 11-ft TWT
 - Perform a baseline survey from Mach 0.4 to 1.35 at $P_t = 2200$ psf.
 - Measure at different tunnel total pressure.
 - Evaluate off centerline levels.
- Measure the background noise level with a fairing attached to the strut trailing edge.
 - Assess the fairings' effect on the spectra.
 - Calculate the reduction in acoustics and turbulence.

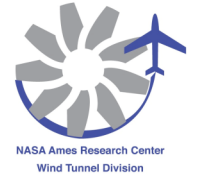


Flow Quality Test Plan

- Phase 1: Repeat 1999 Baseline measurements
 - Unreliable Constant Temperature Anemometer (CTA) cast doubt on the quality of the measurements.
 - P' measurements were higher but transducer referencing strategy was in doubt.
- Phase 2: Acoustic survey to establish new Baseline
 - Mach 0.4 to 1.35 using two rakes
 - Evaluate different probes and referencing methodologies
 - Analysis showed previous content thought to be associated with the drive tone may actually be from the sting model support strut.
- Phase 3: Turbulence Survey with new CTA
 - Mach 0.4 to 0.95.
 - Measure the background noise level with a fairing attached to the strut trailing edge.
 - Assess the fairings' effect on the spectra.
- Phase 4: Supersonic Turbulence Survey
 - Mach 1.05 to 1.5
 - 10° Laminar Flow Cone
 - Free-stream turbulence levels in the 11-ft TWT (establish baseline)



Test Section Instrumentation

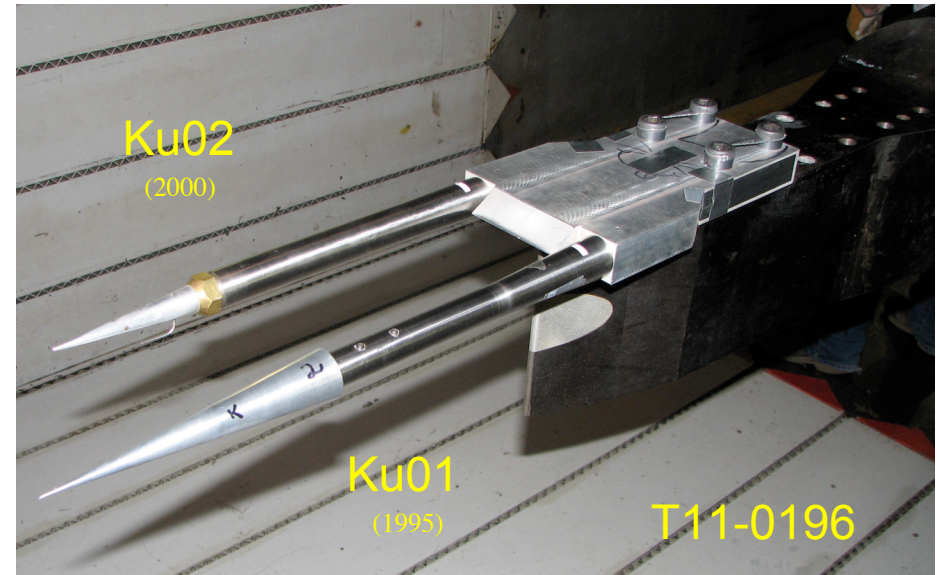


8-Ft Span Rake (Mach < 0.95)



- Turbulence, pu' :
- Fluctuating Static Pressures, p' :
- Total Temperature, T_t :

1-Ft Span Mini-Rake (Mach > 1.0)

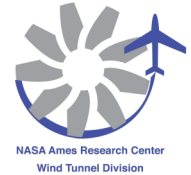


Sensors located at TS 185

single hot wires
10° cone probes
RTD probes



Data Acquisition and Reduction



Data acquired using both a steady state and dynamic system:

Tunnel Condition, rake position

- Standard Data System (SDS)
- Sample period: 1 sec

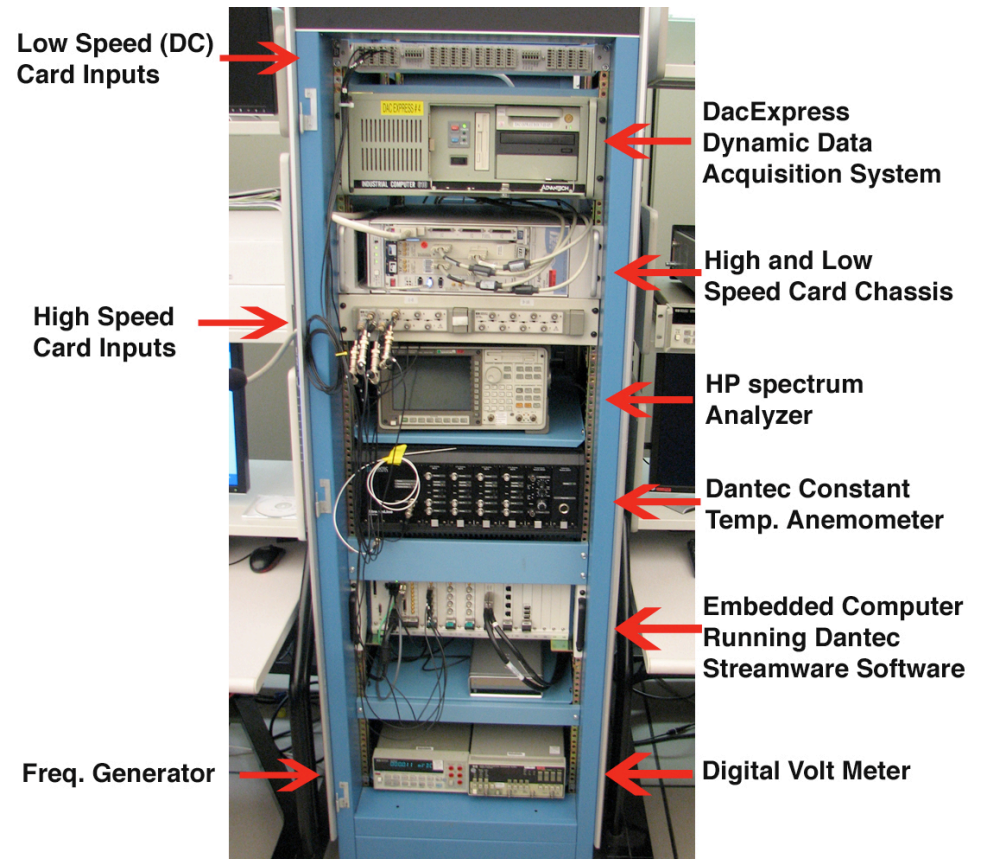
Hot Wire and P' transducers

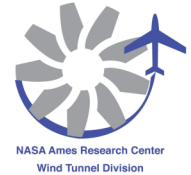
- HP® DAC Express
- Sample rate: 256000 samples/sec
- Sample period: 30 sec
- Signal AC coupled at 0.1 Hz

Data processed with custom software

Processing parameters

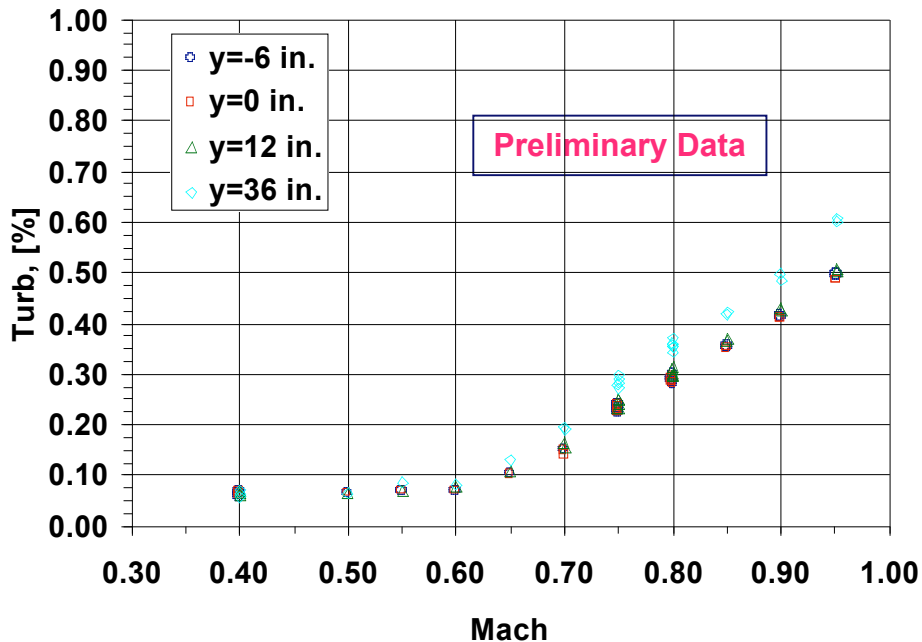
- Bandwidth: 1 Hz to 10 kHz
- Window: Hanning
- PSD resolution: 1Hz
- Overlap: 50%



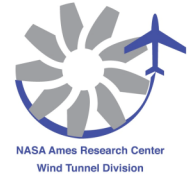


Baseline Turbulence

Pt=2200 psf, z=0 in.

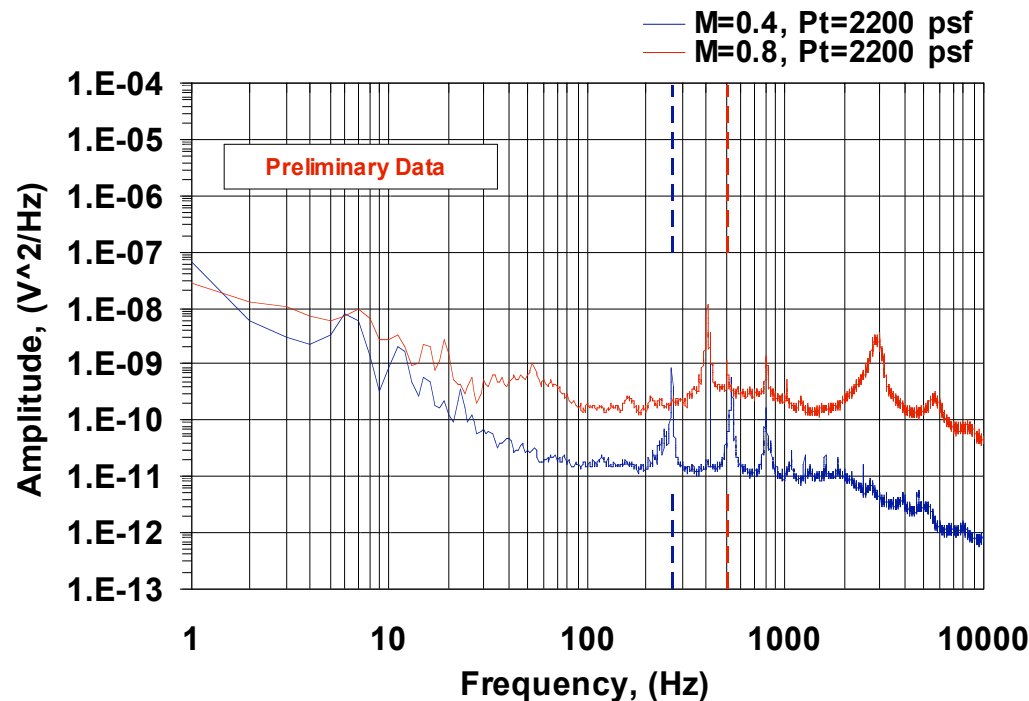


- % Turbulence ($\rho u' / \rho U$) is the metric used to compare overall turbulence levels.
- Each symbol represents the average of 5 data points.
- Centerline probe data agree.
- Elevated level at y=36 in a result of proximity to the walls.



Structure of Turbulence

Pt=2200 psf, z=0 in.



The Power Spectral Density (PSD) plot offers a detailed look into the components that make up the total turbulence.

Major sources of flow perturbation contributing to turbulence (and noise)

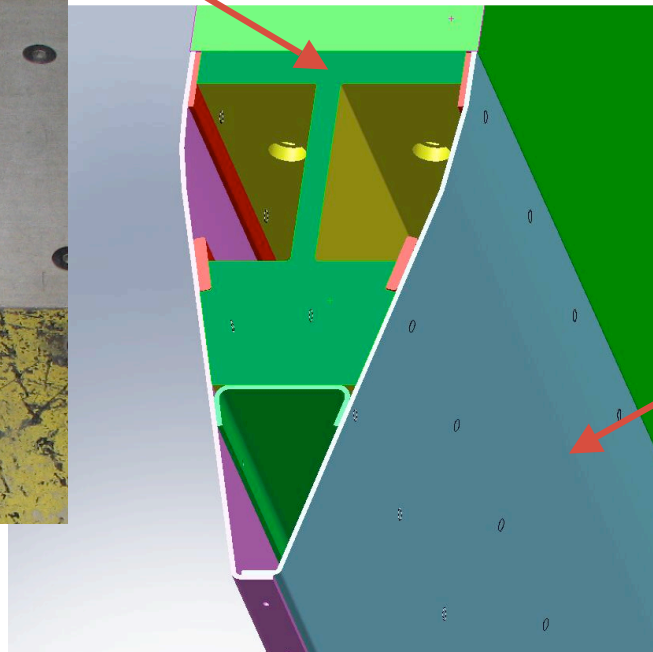
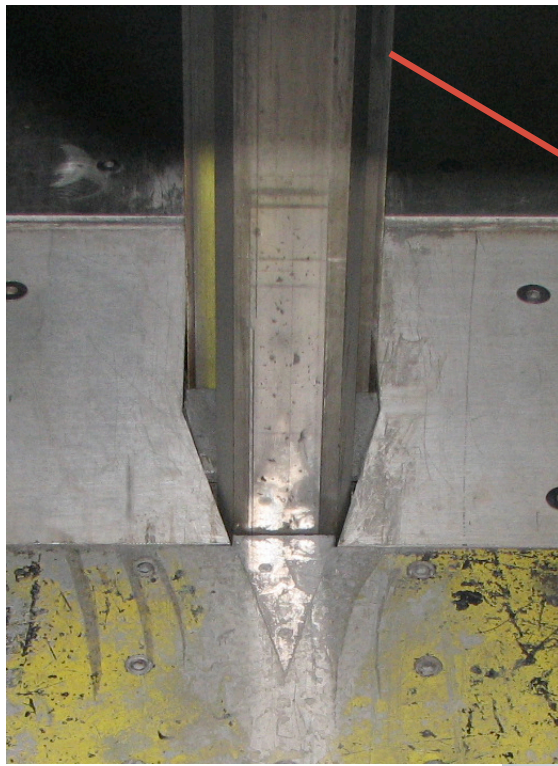
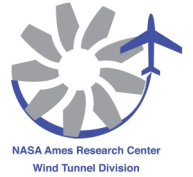
1. SMSS Strut: 200-400 Hz
2. Compressor: 180-650 Hz
3. TS Wall Slots: 2.5-3 kHz

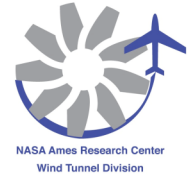
Acquisition: Duration: 30 sec
Sample rate: 25.6 ksamples/s
AC coupled, 0.1 Hz

Processing: Bandwidth: 1 Hz to 10 kHz
Window: Hanning
PSD Resolution: 1 Hz
Overlap: 50%

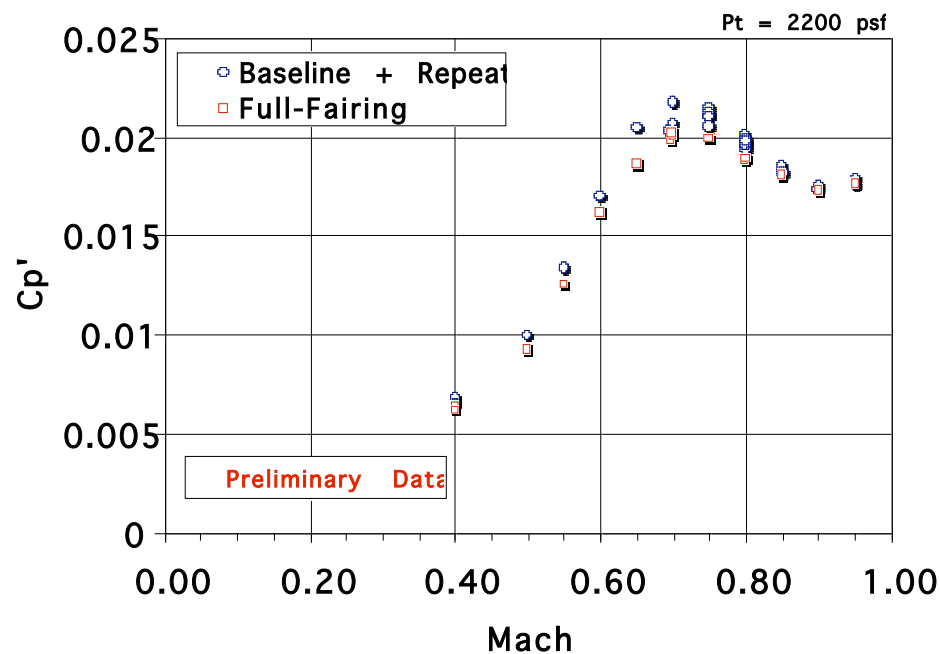


Sting Model Support Strut Noise Reduction Long Fairing

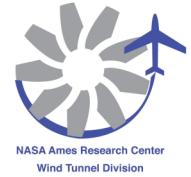




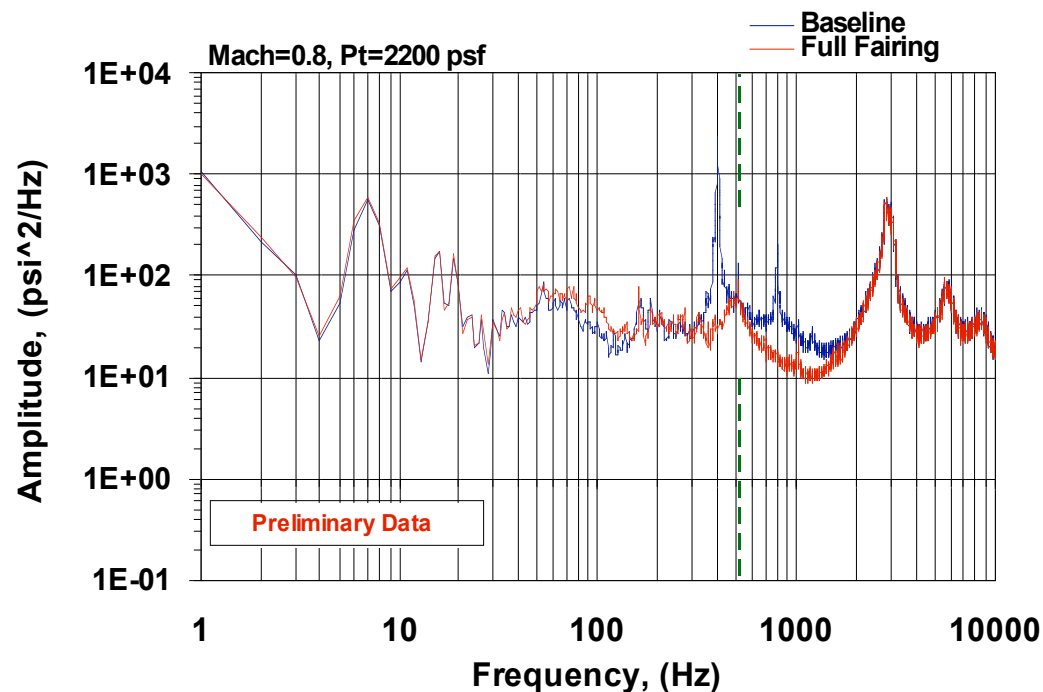
Potential for Acoustic Reduction



- C_p' is the metric used to compare overall noise levels.
- Each symbol represents the average of 5 data points.
- Fairing reduced the C_p' by as much as 10%



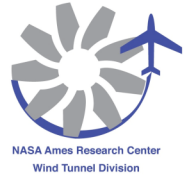
Potential for Acoustic Reduction - PSD



- Acoustics PSD is similar in structure to the one for turbulence.
- The lower C_p' associated with the fairing is a result of the strut tone suppression at 400 Hz.
- Turbulence levels also decrease as a result of this noise reduction.



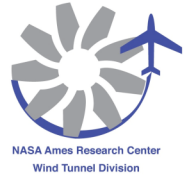
Summary



- New baseline turbulence levels have been measured using a new CTA and new hot-wire sensors.
 - Levels remain the same as measured in 1999.
 - Data and methodology documented (almost)
- New baseline acoustics levels have been measured up to Mach 1.35
 - Levels are higher than reported in 1999.
 - Data and methodology documented (almost)
- Application of fairings to the strut trailing edge showed up to a 10% reduction in the tunnel background noise.
- Data analysis and documentation for publishing is ongoing.



Future



- Perform the Supersonic turbulence survey to establish a baseline
 - Manufacture a new 4-Ft Span Rake to hold more sensors
 - Extend transonic measurement methodology to supersonic flow
 - Design new acoustics probes
- Explore methods to reduce noise generated by slot tones and drive tones.
- Collaboration with customers to determine application to testing requirements.